Rationale for Developing Integrated Multi-trophic Aquaculture (IMTA): an example from Canada

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MARINE aquaculture in Canada is still at an early stage of development after almost three decades of expansion. It is still relatively small on a worldwide scale (0.17 versus 27.68 million tonnes in 2002), but significant on a local scale. For example, in New Brunswick, it is the first agro-food sector of the province (valued at CDN$188.2 million versus CDN$169.1 million for fisheries and CDN$101.2 million for potatoes in 2003). The finfish aquaculture sector in Canada plans to continue to grow in production after leveling off in recent years, but is currently debating how it can do so in a responsible, sustainable, and profitable way.

As the volume of production goes up, the cost of production usually goes down due to implementation of automated technologies and economies of scale. In a commodity market, this usually results in lower prices to the consumer and lower margins for the producers due to competition from other large-scale producers. The result of this expansion is that more profits (to either the owners or the investors) can only be realized from the production side by increasing volume. In the fixed spatial area of a farm, this generally results in pushing the environmental carrying capacity to the limit. Maintaining sustainability, not only from an environmental, but also from economic, social and technical perspectives, has become a key issue. What are, then, the options for facing these challenges?

Geographical expansion is still possible in some areas (for example, Newfoundland and British Columbia), but for how long? There is only a finite amount of appropriate space. In New Brunswick, site access and availability are already limited and public resistance is growing against further expansion of the current aquaculture model. Moving from sheltered nearshore sites to exposed nearshore sites and offshore sites has been contemplated, but technical and economic challenges remain, especially in regions where the coastal zone is already used by many other traditional stakeholders. Offshore development, proposed by some as the next frontier in aquaculture, is not necessarily the appropriate solution for all regions. It is obvious that, sooner or later, the scope for geographic expansion will be limited for existing monoculture technologies and practices.

Photo: Manav Sawhney.

Blue mussel (*Mytilus edulis*) raft and a mussel sock grown next to Atlantic salmon (*Salmo salar*) cages at an integrated multi-trophic aquaculture (IMTA) site in the Bay of Fundy, Canada.

If the expansion of finfish aquaculture is limited in spatial extent by biological and social factors, one obvious solution is to increase the production from existing sites. When considering the seawater volume available at a lease site and the volume of water actually occupied by salmon cages, it is noticeable that a cultivation unit is not optimized. More advanced technology will thus be a prerequisite for intensification. As with the issue of concentrated housing for humans, there will have to be a high degree of living space for organisms, and efficient systems for food delivery, waste treatment, and energy supply. Consequently, intensification will require: 1) innovative and environmentally friendly technologies, 2) new and better management practices and codes, and 3) recognizing aquaculture within a broader integrated coastal management framework.

Diversification of the Canadian aquaculture industry is also imperative to reduce the economic risk and maintain competitiveness. In 2004, the salmon aquaculture in Canada represented 66.7% of the tonnage of the aquaculture industry and 74.7% of its farmgate value. The traditional view of diversification often involves producing a second product that is similar to the first and fits into the existing production and marketing systems. In finfish aquaculture, this has usually meant salmon, cod, haddock or halibut. However, from an ecological point of view, these are all "shades of the same colour". True ecological diversification means a change in trophic level (*i.e.* switching from finfish to another group of organisms such as shellfish, seaweeds, worms, bacteria, etc.). Staying at the same ecological trophic level will not address environmental issues because the system will remain unbalanced and no recycling of nutrients will occur. Since the costs of physiological metabolism are high for any organism, single species systems are doomed to inefficiency. Economic diversification should also mean looking at seafood from a different angle. Aquaculture products on the market today are similar to those obtained from the traditional fishery of yesterday and thus are often in direct competition. While this may be part of the market forces at work, the opportunity exists to diversify from fish filets (or mussels and oysters) on a plate in a restaurant, to a large untapped array of bioactive compounds of marine origin (*e.g.* pharmaceuticals, nutraceuticals, functional foods, cosmeceuticals, botanicals, pigments, agrichemicals, biostimulants, etc.). Research and development on alternative species should no longer be considered as R&D on alternative finfish species, but rather on alternative marine products.

Changes in attitudes are also needed. There is a paradoxical situation when looking at worldwide food production. In agriculture, 80% of the production is made up of plants and 20% of meat, while in aquaculture, 80% of the production is meat and 20% is plants. Regarding mariculture, production is made up of 46.2% molluscs, 44% seaweeds, 8.7% finfish, 1.0% crustaceans, and 0.1% various other animals. In many parts of the world, aquaculture is not synonymous with finfish aquaculture, as many people in affluent western countries believe. In a global market economy, we need to be aware of the other food production systems in the rest of the world if we want to understand our present system and correctly position it in perspective with other systems.

The challenge, then, is how to increase the production capacity of an existing site when the available options have shown their limitations. One of the possible answers is to increase the level of technology involved in the production of seafood so that food and waste handling systems are all actively considered in the growing operation from the start, and are modelled after natural ecosystems. One of the innovative solutions our R&D group is actively developing for environmental sustainability, economic diversification and social acceptability, is integrated multi-trophic aquaculture (IMTA). This practice combines, in the right proportions, the cultivation of fed aquaculture species (*e.g.* finfish) with organic extractive aquaculture species (*e.g.* shellfish) and inorganic extractive aquaculture species (*e.g.* seaweed), for a balanced ecosystem management approach that takes into consideration site specificity, operational limits, and food safety guidelines and regulations. The aim is to increase long-term sustainability and profitability per cultivation unit (not per species in isolation, as is done in monoculture), as the wastes of one component (finfish) are captured and converted into fertilizer, food and energy for the other components (seaweed and shellfish), which can in turn be sold on the market as other marine crops. In this way, all the cultivation components have economic value, and each has a key role in services and recycling processes of the system.

The paradox is that IMTA is not a new concept. Asian countries, which provide more than two-thirds of the world's aquaculture production, have been practicing IMTA for centuries. A renewed interest in IMTA practices emerged in western countries in the late 1980s and early 1990s, based on the common-sense approach that the solution to nutrification is not dilution, but conversion within an ecosystem-based management perspective. The determination to develop IMTA systems will, however, only come about if there are visionary changes in political, social, and economic reasoning. This will be accomplished by seeking sustainability, long-term profitability and responsible management of coastal waters. It will also necessitate a change in the attitude of consumers towards eating products cultured in the marine environment, in the same way that they accept eating products from recycling and organic production systems on land, for which they are willing to pay a higher price.

Photo: Shawn Robinson.

Harvesting of kelp (*Laminaria saccharina*) cultivated in proximity to Atlantic salmon (*Salmo salar*) at an integrated multi-trophic aquaculture (IMTA) site in the Bay of Fundy, Canada.

Our interdisciplinary team of scientists from the University of New Brunswick and the Department of Fisheries and Oceans has been working on a salmon/mussel/kelp IMTA project in the Bay of Fundy since 2001 with the support of AquaNet, the Canadian Network of Centres of Excellence for Aquaculture. This project, like several others in different parts of the world (*e.g.* Chile, Israel, Scotland, the USA, South Africa, Australia), is on the verge of making the biological demonstration of the validity of the IMTA concept (*e.g.* significant increases of kelp and mussel production (46% and 50%, respectively) in proximity to salmon sites due to a more beneficial use/conversion of food and energy; advantages of environmental services through bioremediation and diversification of the crops; absence of transfer of therapeutants and chemicals used in salmon aquaculture to the kelps and mussels).

The next step in our project is the scaling up of operations with our industrial and government partners (Cooke Aquaculture Inc., Acadian Seaplants Limited, Ocean Nutrition Canada, the Canadian Food Inspection Agency, the Atlantic Canada Opportunities Agency, and the New Brunswick Innovation Foundation) to make the biological demonstration at a commercial scale, and to document the economic and social advantages of the concept, which will be key to convincing practitioners of monospecific aquaculture to move towards IMTA practices. To move from the R&D pilot scale to the scale-up commercial stage, some federal and provincial regulations and policies need to be changed or they will be impediments to industry. We are presently working with the Department of Fisheries and Oceans (DFO), the Canadian Food Inspection Agency (CFIA) and Environment Canada (EC) on amending the Canadian Shellfish Sanitation Program (CSSP), based on the recent and reliable data and information provided by our project and other similar ones.

The appropriate financial tools conducive to the development of IMTA will also have to be put in place. It is important to note that present aquaculture business models do not consider and recognize the economic value (valued-added crops and environmental services) of bioremediation by biofilters, as there are no costs associated with aquaculture discharge/effluent in open seawater-based systems. Regulatory and financial incentives may therefore be required to clearly recognize the benefits of the extractive components of IMTA systems (shellfish and seaweed). A better estimate of the overall cost/benefits to nature and society of aquaculture waste and its mitigation would create powerful financial and regulatory incentives to governments and the industry to jointly invest in the IMTA approach.

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